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SOIL PENETROMETER

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16 Claims. (Cl. 73—81)

This invention relates to devices for burrowing into soil formations and, more particularly, to an auger-type soil penetrometer.

The invention described herein was made in the performance of work under NASA contract and is subject to the provisions of the National Aeronautics and Space Act of 1958, Public Law 85-568 (72 Stat. 426; 42 U.S.C. 2451), as amended.

Auger-type soil penetrometers are known. Existing auger-type penetrometers have the common characteristic that the auger is coupled to the lower end of a substantially rigid rotatable member or drive shaft. In view of the rigidity of the drive shaft, the auger can be moved only along a line corresponding to the initial direction of the shaft at the surface of the soil. Accordingly, such penetrometers can be used to obtain soil characteristic measurements only to the depth to which the auger can be driven along a substantially straight line. If the auger should encounter a buried boulder, for example, the rigidity of the drive shaft does not permit the auger to deviate from its basic predetermined path.

This invention provides a soil penetrometer which has the feature that the auger, while initially moving along a predetermined path, may deviate from such path when the auger encounters a buried boulder or the like. Accordingly, the depth to which this penetrometer may be used is not limited by the existence of buried boulders and other local impediments to the movement of the auger through the soil. Moreover, the penetrometer is not restricted to deriving soil characteristic data solely from the torque required to drive the auger. Accordingly, increased information about the soil through which the auger moves may be obtained.

Generally speaking, this invention provides apparatus for burrowing into the earth. The apparatus includes an elongate coilable torque transmitting member and coiling means for the torque transmitting member at one end of the member. An auger is connected to the other end of the torque transmitting member so as to be driven in response to rotation of the torque transmitting member. A base is also provided. Support means for the coiling means are mounted to the base for rotation relative to the base. The torque transmitting member extends from the coiling means to the auger along the axis about which the support means is rotatable relative to the base. The apparatus also includes drive means coupled to the support means operable to rotate the support means about said axis to rotate the torque transmitting member, thereby to drive the auger.

The above-mentioned and other features of the present invention are more fully set forth in the following detailed description of the invention, which description is presented in conjunction with the accompanying drawings, wherein:

FIG. 1 is a cross-sectional elevation view of a soil penetrometer according to this invention;

FIG. 2 is an elevation view, with parts omitted, taken along line 2—2 of FIG. 1;

FIG. 3 is a cross-sectional elevation view of another soil penetrometer according to this invention;

FIG. 4 is a cross-sectional elevation view taken along lines 4—4 of FIG. 3; and

FIG. 5 is a cross-sectional elevation view taken along lines 5—5 of FIG. 3.

FIG. 1 shows a soil penetrometer 10, the penetrometer comprising a presently preferred embodiment of this invention. The penetrometer includes a base 11 having a horizontal portion 12 engaged with the surface of a soil formation 13 in which measurements of soil characteristics are to be made. The base member also has a vertical portion 14. The ground engaging portion of the base member is open at 15 to permit the passage of auger 23 into the soil formation.

An elongated, flexible and coilable torque transmission shaft 18 has one of its ends connected to a rotatable drum 19. The flexible shaft preferably is constructed of several concentric, tightly wound wire coils, alternate coils being wound in opposite directions as shown in FIG. 5 relative to shaft 74. Such flexible torque transmitting shafts are known and, therefore, shaft 18 is not illustrated in greater detail. Drum 19 defines a single helical groove 20 around and along its exterior surface to receive substantially the entire length of the flexible shaft. The drum comprises coiling means for the flexible shaft.

The flexible shaft passes from drum 19 through opening 15 to the upper end of the body 22 of an auger 23 having a helical auger blade 24 secured to and wound around the exterior of the auger body. The lower end of the auger body is pointed. The auger is constructed so that it either advances through, or retracts itself from, soil with which it is engaged, depending upon the direction of rotation of flexible shaft 18.

Shaft coiling and storage drum 19 is mounted on a horizontally disposed shaft 25. The drum is mounted to the shaft so that the drum and shaft rotate together and so that the drum may move axially along the shaft. Axial movement of the drum along shaft 25 is produced by the cooperation of flexible shaft 18 with helical grooves 20 as the drum is rotated to reel in or pay out the flexible shaft in accord with axial movement of the auger.

The drum is rotatably mounted at its opposite ends in a support member 26. The support member is in turn rotatably mounted in a frame 27 which is mounted in cantilever fashion to the vertical portion of base 11. The support member has upper and lower axles 28 and 29, respectively, which are rotatably mounted to the frame. The support member axles are aligned along a vertical axis 30 about which the support member is rotatable relative to the base. Axle 29 is axially bored at 31 so that the flexible shaft 18 may be passed through it to the auger. A guide tube 32 for the flexible shaft is mounted to the lower axle and extends from bore 31 into substantial tangency with drum 19 to guide the flexible shaft into registry with groove 20.

Frame 27 is mounted to base 11 at its upper end by a link 34 pivotally connected at its opposite ends to the frame and to the base member, respectively. The frame is mounted at its lower end to the base by a flexure arm 35. One end of the flexure arm is pivotally connected to the frame; the other end of the flexure arm is rigidly connected to the base. The frame thus is mounted to the base for limited movement along axis 30. The frame is further supported on the base by a spring 36 engaged between the frame and base portion 12. The spring urges the frame into a selected position along the axis in which flexure arm 35 is relatively unstressed. The spring is disposed around a telescoping post assembly 37 which prevents buckling of the spring.

Penetrometer 10 includes means for rotating the support member relative to the base. A motor plate 39 is rotatably mounted to support member axle 29 above the lower extent of the frame. An electric motor 40 is mounted to the motor plate and depends through an

opening 41 in the frame. The motor has an upwardly extending output shaft 42 to which a pinion gear 43 is secured for engagement with a spur gear 44 which is secured to axle 29 above the motor plate. The motor plate is held substantially stationary relative to the frame by a force gage assembly 45. Force gage assembly 45 is similar to the gage structure shown in FIG. 4 and permits only slight relative movement between the motor plate and the frame. The force gage assembly, however, includes a pair of springs (not shown) which urge the motor plate into a normal or reference position angularly relative to the frame. The force gage assembly is provided to continuously measure the torque imparted to flexible shaft 18 to drive the auger in response to rotation of the support member. Operation of motor 40 produces rotation of support member 26 about axis 30 so that the flexible shaft is rotated to drive the auger.

Soil penetrometer 10 also includes means for reeling the flexible shaft to and from drum 19 and for maintaining the flexible shaft in tension as the auger is rotated. An electric motor 46 is mounted to the drum support member below the drum. The motor has a rotatable output shaft (not shown) which extends horizontally parallel to shaft 25. The motor output shaft comprises the input shaft of a friction-type adjustable slip clutch 47 which has a rotatable, horizontally extending output shaft 48. A pinion gear is secured to shaft 48 and is engaged with a spur gear 49 secured to drum shaft 25.

As the flexible shaft is rotated by opertaion of motor 40 to advance the auger through soil formation 13, the flexible shaft is urged to unreel from drum 19 at the same rate at which the auger advances. Motor 46 is operated to rotate drum 19 in the direction of flexible shaft payout, but at a rate which, if the drum were positively linked to the motor, would drive the drum at a slower rate. The torque imposed upon the drum by motor 46 via slip clutch 47, however, is less than the torque imposed upon the drum by the tension in the flexible shaft. Accordingly, the clutch slips and shaft 48 overruns the motor shaft. The slip clutch, however, imposes a drag upon the drum so that the flexible shaft is kept under tension as the auger is advanced. The amount of the drag imposed upon the drum is determined by the adjustment of the slip clutch. It is desired that tension be maintained on the flexible shaft as the auger is advanced to provide a guiding drag upon the auger and to prevent the flexible shaft from twisting itself into knots as a result of the torque developed in it.

Tension is also maintained in the flexible shaft when the flexible shaft is rotated in the opposite direction to recover the auger. In this case, tension is desired to provide a guiding pull on the auger and to prevent the shaft from twisting itself into knots. When the auger is being rotated to cause it to back out of soil formation 13, drum drive motor 46 is operated to cause the drum to reel in the flexible shaft. Motor 46 is operated at a rate which, but for slip clutch 47, would cause the flexible shaft to be reeled in at a rate greater than the rate of movement of the auger. The slippage provided by the slip clutch, however, permits the drum to reel in the flexible shaft at the rate at which the auger burrows out of the soil formation. The setting of the slip clutch determines the amount of tension imposed upon the flexible shaft.

Penetrometer 10 is instrumented so that measurements of the characteristics of the soil through which the auger passes may be obtained. As noted above, a force gage assembly 45 is coupled to motor plate 39 for measuring the torque imparted to the auger; it will be understood, however, that the torque delivered to the auger may be measured at the auger, if desired. The penetrometer also includes means for measuring the tension in the flexible shaft. A pair of electrical strain gages 51 are bonded to the upper and lower surfaces, respectively, of flexure member 35. As noted above, frame 27 has a predetermined position relative to base 11 in which the flexure member, or at least the strain gages secured to the flexure member, are unstressed. When the auger is engaged with the soil formation and tension is imparted to the flexible shaft, the frame is moved toward the base and the flexure member is deformed. The deformation of the flexure member is proportional to the tension in the flexible shaft. The strain gages, therefore, comprise a means for measuring this tension.

The penetrometer also includes means for relating the measurements of torque delivered to the auger and of tension in the flexible shaft to the position of the auger in the soil formation. A multi-turn potentiometer 54 is coupled to one end of drum shaft 25. The output of the potentiometer is directly related to the amount of flexible shaft payed-out from the drum and thus is a measure of the position of the auger in the soil formation. Frame axle 28 carries three slip rings 5 to which are connected, respectively, the opposite ends of the potentiometer wiper. The slip rings cooperate with wiper brushes which extend from a supporting housing 56 mounted to frame 27. Axle 28 also carries slip rings 57 by which electrical power is supplied to motor 46.

To assure that auger 23 is properly engaged with soil formation 13 as operation of penetrometer 10 is commenced, an auger guide assembly 59 is mounted to support member 26. The auger guide assembly includes a hollow tube 60 secured to the lower end of support member axle 29 below frame 27. Tube 60 is disposed concentric to axis 30 and has an open lower end defining an inwardly extending peripheral flange 61. A hollow tube 62 is slidably mounted in tube 60 for telescoping movement along axis 30 relative to tube 60. Tube 61 has an outwardly extending circumferential flange 63 at its upper end which is engageable with flange 61 to prevent disengagement of the tubes. The inner diameter of the inner tube is sized to receive the upper end of auger body 22. In the drawing the distance between frame 27 and base portion 12 has been foreshortened for purposes of compactness of illustration; workers skilled in the art will appreciate that the penetrometer is constructed so that the pointed lower end of the auger lies above the bottom surface of the base when the auger is fully retracted.

Another soil penetrometer 70 according to this invention is shown in FIGS. 3–5. The penetrometer includes a base 71 (similar to base 11), a frame 72 (similar to frame 27), and a support member 73. The penetrometer also includes an elongated, flexible and coilable torque transmission shaft 74 which is like shaft 18. One end of the flexible shaft is connected to a shaft storage and reeling cage 75 and the other end of the flexible shaft is secured to the upper end of an auger (not shown but like auger 23).

Cage 75 is hollow and has a conical lower end 76 and a cylindrical upper end 77. Shaft 74 is connected to the cage so that as the cage is rotated about a vertical axis 78 of the penetrometer, the shaft is coiled around the interior of the upper end of the cage. The cage is secured to support member 73 so that the cage is mounted for rotation with the support member relative to the base.

The support member has a downwardly extending axially bored axle 79 which is rotatably mounted to frame 72 concentric to axis 78. The upper end of the cage is rotatably mounted to the frame along the axis by a potentiometer housing 80 secured to the upper end of the cage and by a shaft 81 engaged between the frame and the housing. The frame, in turn, is mounted to the base for limited axial movement along axis 78 by a link 34, a flexure member 35 and a spring 36. The base defines an opening 15 through it along axis 78 so that the auger may be engaged with soil formation 13 on which the base is supported.

Adjacent the lower end of cage 75, the support member carries a spur gear 83 concentric to axis 78. The spur gear is engaged with a worm gear 84 (see FIG. 4) which is mounted to the output shaft 85 of an electric motor 86. Motor 86 is mounted to a motor plate 92. Shaft 85 at opposite ends of the worm gear is mounted

in bearings 87 which are carried by the motor plate. Operation of the motor rotates the support member and the cage about axis 78 so that the flexible shaft is rotated to drive the auger.

Penetrometer 70, like penetrometer 10, includes a force gage assembly 90 for measuring the torque imported to flexible shaft 18 to drive the auger. The bearing which journals the end of shaft 85 opposite from motor 86 is mounted by a pedestal 91 to motor plate 92 which is slidably mounted to the frame, as by a dovetail connection, for example, for linear movement relative to the frame in the plane of spur gear 83. Motor 86 is also mounted to the motor plate. Intermediate the bearing and the motor plate, pedestal 91 defines a hole 93 through it parallel to the line of movement of the motor plate relative to the frame. A guide pin 94 is passed through hole 93 and is mounted at its opposite ends to respective ones of a pair of brackets 95 which are fixed to frame 72. A compression spring 96 is disposed around pin 94 between the pedestal and each bracket. The springs urge the motor plate into a selected position relative to the frame. The motor plate carries the armature 97 of a differential transformer 98 which has its primary winding 99 and its secondary windings 100 fixed relative to the frame. Depending upon the amount and direction of the torque imparted to the flexible shaft by operation of motor 86, the motor plate moves in one direction or the other relative to the frame from the normal position of the motor plate. This movement is proportional to the torque which is delivered to the auger. The output of the differential transformer, therefore, is a measure of this torque.

Workers skilled in the art to which this invention relates will appreciate that some mechanism other than a differential transformer may be used to measure the torque delivered to the auger, if desired. For example, strain gages may be used in conjunction with a strain member coupled between the motor plate and the frame. Alternatively, motor 86 may be fixed directly to the frame and the power required to operate the motor at a given speed may be used as a measure of the torque delivered to the auger. The use of a differential transformer has been described and shown merely for the purposes of illustration and example.

Penetrometer 70 also includes means for reeling the flexible shaft to and from cage 75 and for maintaining the flexible shaft in tension as the auger is rotated so that the maximum torque transmitting capacity of the flexible shaft is utilized. A drive pulley 104 for the flexible shaft is disposed in a chamber 105 in support member 73 so that the drive pulley is oriented in a plane parallel to axis 78 and is engaged with the flexible shaft along the length thereof which passes through an axial bore 106 through the support member. The pulley cooperates with an idler wheel 107 which is rotatably mounted in chamber 105 for engagement with the side of the flexible shaft opposite from the drive pulley. The drive pulley is secured to a shaft 108 which is the output shaft of a friction-type slip clutch device 109. The slip clutch has as its input the rotatable output shaft (not shown) of an electric motor 110 (see FIG. 5). Motor 110 is operated to drive pulley 104 in the same manner that motor 46 is operated to drive drum 19 to maintain tension in flexible shaft 74, regardless of the direction of rotation of the flexible shaft and regardless of the direction of movement of the flexible shaft through bore 106.

An auger receiver and guide assembly 59, in accord with the foregoing description, is secured to the lower end of support member 73 below frame 72 concentric to axis 78.

A strain gage 51 is bonded to each of the upper and lower surfaces of flexure member 35 for measuring the tension imposed upon flexible shaft 74.

The instantaneous depth of the auger in soil formation 13 is measured by the output of a multi-turn potentiometer 110 which is mounted within housing 80 to the upper end of cage 75 concentric to axis 78 for rotation with the cage. The wiper of the potentiometer is connected to a rotatable shaft 111 which extends from the potentiometer into the cage along axis 78. A flexible shaft follower arm 112 is connected to the shaft in the cage for rotation with the shaft. The follower arm is engaged with the flexible shaft. As the flexible shaft is reeled into or out of the cage, even during rotation of the cage to rotate the flexible shaft, the follower arm, by reason of its engagement with the flexible shaft, is rotated relative to the cage. Since the flexible shaft is coiled for storage within the cylindrical upper end of the cage, the rotation of shaft 111 is directly related to the depth of the auger in the soil formation. Thus, the output of potentiometer 110 is a measure of the depth of the auger.

Three slip rings 114 are mounted to the exterior of housing 80 and cooperates with a like number of brushes 115 which extend from a brush holder 116 mounted to the upper end of frame 72. Respective ones of slip rings 114 are conductively connected by wires (not shown) to the opposite ends of the potentiometer winding and to the potentiometer wiper. Three additional slip rings 117 are mounted to housing 80 for coopertaion with a like number of brushes 118; these slip rings are conductively connected to the input terminals of motor 110.

Penetrometers 10 and 70 are operated in similar manners to obtain data from which certain characteristics of soil formation 13 may be inferred. The penetrometer is disposed over a desired location of the soil formation; as noted above, at this time the auger is fully retracted so that its lower end is above the bottom surface of penetrometer base 11. Motors 40 and 46 (or motors 86 and 110) are operated to rotate the flexible shaft and to pay the flexible shaft from its coiling means. As the flexible shaft is payed out, auger receiver and guide assembly 59 guides the auger along axis 30 (or axis 78) into engagement with the soil formation. The auger is kept in contact with the guide assembly long enough to assure that the auger commences its movement through the soil formation along an imaginary extension of the axis of rotation of the support member; thereafter the drag or tension in the flexible shaft serves to maintain the auger along such a path until a buried boulder or the like is encountered by the auger. In the event the auger encounters a boulder or other localized impediment to its further progress along axis 30 or 78, the auger may follow along the normally curved surface of the boulder until it has moved to the side of the boulder. The auger may then continue to burrow downwardly past the boulder, although it may now follow a path which lies at an angle to its path before the boulder was encountered.

As described above, the penetrometer is instrumented so that measurements of the torque delivered to the flexible shaft, and thus to the auger, are continuously obtained. Also, measurements of the instantaneous depth of the auger in the soil formation are continuously obtained via the potentiometer coupled to the flexible shaft coiling means; these measurements are also useful to indicate the rate of advance of the auger. From a knowledge of the torque required to drive an auger of known characteristics through a soil formation at a particular rate, the load bearing and density characteristics of the soil may be determined. Moreover, the shear strength of the soil at any depth may be determined by stopping rotation of the flexible shaft and pulling upwardly on the flexible shaft until the auger moves axially in the soil. The auger is pulled upwardly by positively locking slip clutch 47 (or 109) to motor 46 (or 110) and increasing the power to the flexible shaft tensioning and reeling motor. The pull on the flexible shaft is measured by strain gages 51 as the coiling and drive assembly moves relative to the base from which it is cantilevered. Thereafter, rotation

of the flexible shaft may be resumed to drive the auger to a deeper location in the soil formation.

The auger may be recovered from the soil formation merely by reversing the operation of motors 42 and 46, or motors 86 and 110, as the case may be.

As shown in FIG. 5, a flexible shaft fabricated of several concentric spirally wound wires (adjacent spirals being wound in opposite directions) has a hollow core passage 120. The flexible shaft, therefore, may be used as a conduit for electrical conductors from the auger to the flexible shaft coiling and storage means. Accordingly, if desired, the torque delivered to the auger and the tension on the flexible shaft may be measured at the auger merely by equipping the auger with suitable instrument transducers designed to sense such quantities. Such transducers are within the present state of the instrumentation art and form no part of the present invention per se and thus such an alternative to the abovedescribed structure is not illustrated, although the means whereby such an alternative may be accomplished will be readily apparent to markers skilled in the art to which the present invention relates. It is only necessary to provide additional slip ring and brush combinations in the electrical connection of the coiling means support member to the frame so that signals from the transducers may be obtained at the frame or the base of the penetrometer.

Moreover, if desired, the auger may be equipped with additional transducers and measuring devices whereby additional measurements of desired characteristics of the soil formation may be obtained. For example, thermocouples, radiation counters, moisture sensors, magnetic sensors and the like may be housed in auger body 22, and the conductors by which the output signals of such devices are supplied to the surface of the soil formation may be passed through core passage 120 of the flexible shaft. A penetrometer augmented with such instruments is useful in prospecting for minerals or water, as well as in obtaining measurements of the structural characteristics of soil.

The instrumentation of penetrometers 10 and 70 for measuring torque and tension in the flexible shafts thereof may be eliminated where it is desired to provide apparatus for burrowing into a soil formation to provide an anchor in soils or in soils under water. In view of this utility of structure according to this invention, and also in view of the rugged construction of such structures, it is apparent that the invention may be useful in manned and unmanned explorations of the moon, for example. Apparatus instrumented in accord with the foregoing description may be included in a space vehicle designed for a soft (i.e., non-destructve) landing on the moon. The auger may be operated to cuase it to burrow into the lunar soil so that measurements of certain characteristics of the soil may be obtained. The output signals from the instruments in the apparatus can be applied to a telemetry system in the vehicle for transmission to earth for interpretation and analysis. After the auger has burrowed into the lunar soil, it may serve as an anchor so that the vehicle becomes a stable platform upon which or from which other experiments, such as seismological experiments may be conducted.

From the foregoing, it is apparent that this invention provides a versatile, rugged and effective apparatus for burrowing into a soil formation. The invention may be used for any one of a number of purposes, depending upon whether and how it is instrumented. The invention has been described above in the context of a soil penetrometer, but such a form of the invention has been selected merely for the purposes of explanation and example to one skilled in the art to which the invention relates. Such workers will readily appreciate the true scope of the invention and will understand that alterations and modifications may be made in the structures above-described without departing from the true scope of the invention. Accordingly, it is to be understood that the invention includes the reasonable equivalents of the structures and procedures described, and is not to be restricted to the presently preferred embodiments selected for presentation herein.

What is claimed is:

1. Apparatus for burrowing into a soil formation comprising:

(a) an elongate coilable torque transmitting member,
(b) coiling means for the torque transmitting member at one end of the torque transmitting member,
(c) an auger connected to the other end of the torque transmitting member to be driven in response to rotation of the torque transmitting member,
(d) a base adapted to be supported on the surface of soil formation,
(e) support means for the coiling means mounted to the base for rotation relative to the base,
  the torque transmitting member extending from the coiling means to the auger along the axis about which the support means is rotatable relative to the base, and
(f) drive means coupled to the support means operable to rotate the support means about said axis to rotate the torque transmitting member thereby to drive the auger.

2. Apparatus according to claim 1 wherein the coiling means comprises a hollow conically configured cage disposed above the base and aligned with said axis, the cage having its small end disposed downwardly and opening along said axis.

3. Apparatus according to claim 2 wherein the support means includes a rotatable member mounted to the base for rotation about said axis and disposed between the base and the cage, the lower end of the cage being secured to the rotatable member concentric to said axis for rotation with the rotatable member about said axis, the rotatable member defining a passage therethrough along said axis through which the torque transmitting member extends from the cage to the auger.

4. Apparatus according to claim 3 wherein the drive means comprises a gear secured to the rotatable member concentric to said axis, a motor mounted to the base and having a rotatable output shaft, and gear means interconnected between the motor shaft and the gear for rotating the gear and the rotatable member about said axis in response to operation of the motor.

5. Apparatus according to claim 3 including means for reeling the torque transmitting member into and out of the cage.

6. Apparatus according to claim 5 wherein the reeling means includes a drive pulley rotatably mounted to the rotatable member and engaged with the torque transmitting member along said passage, an idler wheel engaged with the torque transmitting member and rotatably mounted to the rotatable member opposite the torque transmitting member from the drive pulley, and a motor coupled to the drive pulley for rotating the same.

7. Apparatus according to claim 6 including a slip coupling connected between the reeling means motor and the drive pulley permitting relative motion between the pulley and the motor so that the motor may be driven in the same direction as but slower than advancing movement of the auger as the torque transmitting member is payed out from the cage to maintain tension on the torque transmitting member as the auger is advanced, and so that the motor can be driven in the same direction but faster than retreating movement of the auger as the torque transmitting member is reeled into the cage to maintain tension on the torque transmitting member as the auger is recovered.

8. Apparatus according to claim 1 wherein the coiling means includes a drum mounted to the support means for rotation about a second axis normal to the axis about which the support means is rotatable relative to the base.

9. Apparatus according to claim 8 wherein the drive means includes a gear secured to the support means concentric to the axis of rotation of the support means, a motor mounted to the base and having a rotatable output shaft, a gear means interconnected between the motor shaft and the gear for rotating the gear in response to operation of the motor.

10. Apparatus according to claim 8 including means for reeling the torque transmitting member to and from the drum and for maintaining tension on the torque transmitting member during reeling thereof to and from the drum.

11. Apparatus according to claim 10 wherein the reeling and tensioning means includes a motor mounted to the support means for rotation with the support means relative to the base, the motor having a rotatable output shaft and a slip coupling connected between the motor shaft and the drum for rotating the drum in response to operation of the motor and for allowing the drum to rotate at a rate different from that corresponding to the operational rate of the motor in response to loads imposed upon the drum.

12. Apparatus according to claim 1 including means for reeling the torque transmitting member to and from the coiling means and for maintaining the torque transmitting member in tension during rotation of the torque transmitting member.

13. Apparatus according to claim 1 including means for receiving and for guiding the auger into engagement with the soil formation along a selected path.

14. Apparatus according to claim 1 including means for measuring the torque imparted to the torque transmitting member.

15. Apparatus according to claim 14 including means for reeling the torque transmitting member to and from the coiling means and for maintaining the torque transmitting member in tension during rotation thereof, and means coupled to the torque transmitting member operable during rotation thereof for measuring the tension therein.

16. Apparatus according to claim 15 wherein the torque transmitting member comprises a flexible shaft, and means for continuously measuring the amount of flexible shaft reeled out from the coiling means.

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SOIL PENETROMETER

Filed Sept. 20, 1965 3 Sheets-Sheet 1

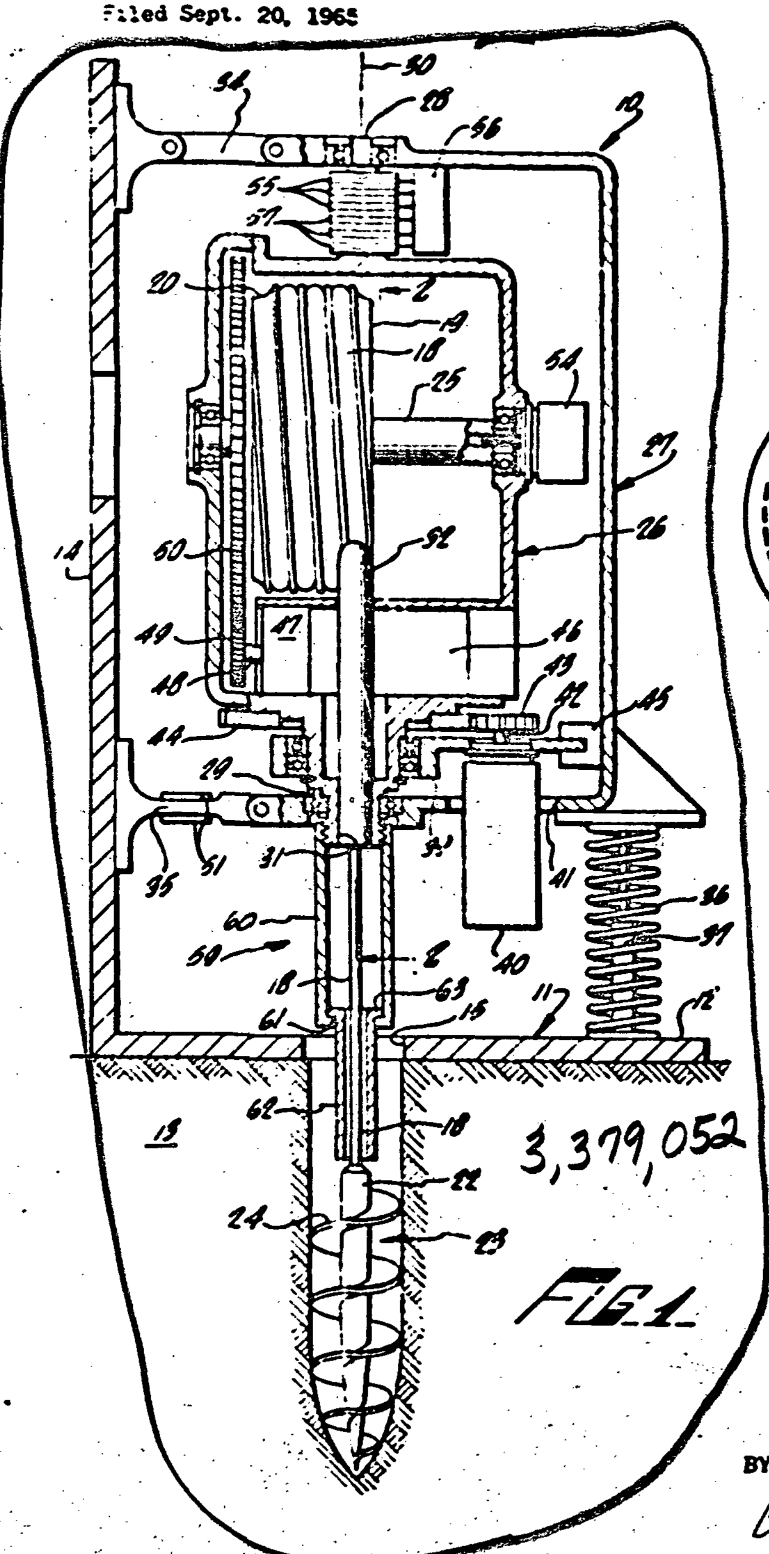

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FIG. 1

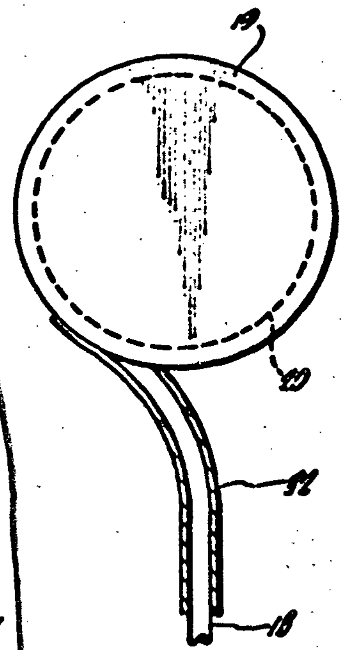

FIG. 2

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SOIL PENETROMETER

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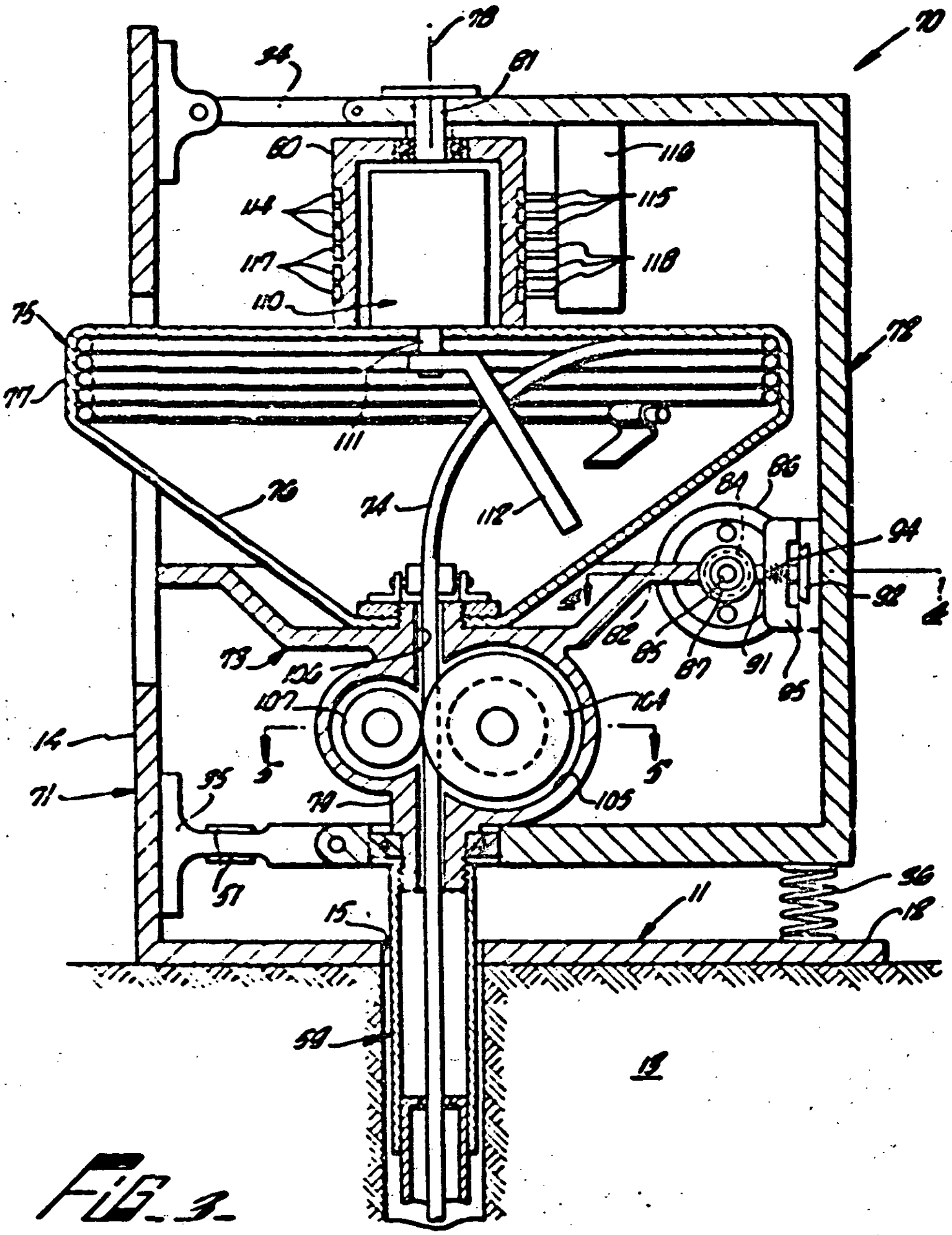

FIG. 3

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FIG. 4

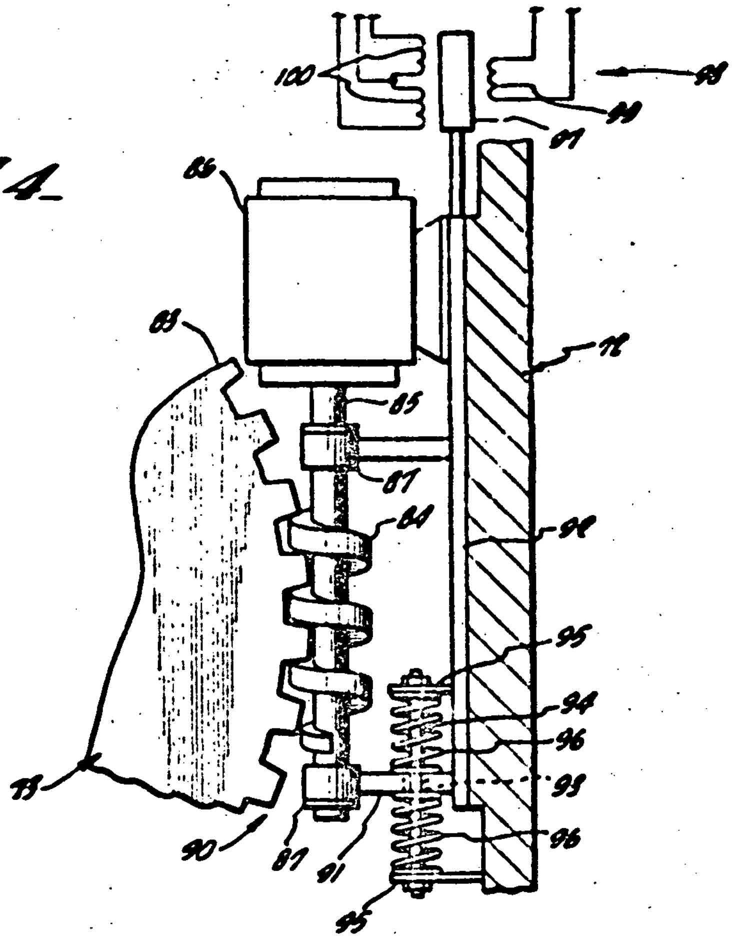
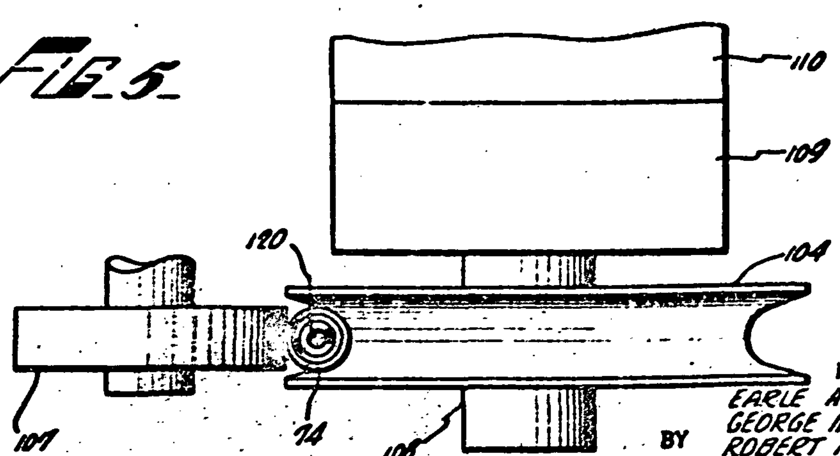


FIG. 5



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